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## Variations on a string bag: Using Pask's principles for practical course design

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This article contains a figure that extends across Pages 8-9. The figure displays properly in Adobe Acrobat 9 with the setting View → Page Display → Two-Up.

**Variations on a String Bag:  
Using Pask's principles for practical course design**

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Keywords:  
relational glossary, learning objectives, relevant assessment

*Abstract: Situation and problem*

A course-writing team needs to converge rapidly to what it regards as:

- |    |                               |                                 |
|----|-------------------------------|---------------------------------|
| 1. | an agreed topic structure     | which is keyed to               |
| 2. | agreed learning objectives    | which specify                   |
| 3. | relevant assessment questions | in a natural learning sequence. |

Only then can the team members go away individually to write, knowing that everything that they write will fit together.

In normal practice, this convergence is only partial:

- |    |   |
|----|---|
| 1. | the topic structure harbors gaps, ambiguities and contradictions  |
| 2. | the learning objectives are not keyed explicitly to the concepts in the topic structure                               |
| 3. | questions for assessment of learners' understanding do not directly exemplify conceptually keyed learning objectives. |

The result is courseware which does not help people to learn as well as it otherwise could, and which has been created with more effort than otherwise would have been needed.

This paper shows how systemic methods inspired by Gordon Pask can be used to complete the necessary convergence with ease.

## *Possibilities and proposal*

Solutions to these three course-writing problems have been sought for many years. In particular:

1. Gordon Pask developed a way to get rid of gaps, ambiguities and contradictions in a conceptual entailment mesh – in ordinary course writers' terms, a topic structure – by using computer-mediated elicitation of the structure over a subject-matter domain (Pask et al., 1973; Pask et al., 1975; Pask, 1975).
2. Bloom, Gagné and Mager, among others, developed 'complete sets' of universally relevant learning objectives (Bloom, 1956; Gagné, 1965; Mager 1962).
3. Brian Lewis showed how questions for assessment of learners' understanding could be made more relevant and more fair if they were keyed to new kinds of learning objectives which were designed to reflect course content closely (Lewis, 1973; Lewis et al., 1974).

Unfortunately, these solutions have fallen short:

1. The relationships in Pask's conceptual entailment meshes are expressed in terms of relational operators instead of phrases from ordinary language. So ordinary course writers cannot easily use his techniques to remove gaps, ambiguities and contradictions from their topic structures and to converge to agreed, shared topic structures.
2. Proposed complete sets of universally relevant learning objectives have not been formulated as direct uses of concepts (i.e. nodes in a topic structure). So ordinary course writers cannot key such learning objectives precisely and explicitly to the concepts in their topic structures.
3. Not even Lewis' keyed learning objectives are formulated as direct uses of course concepts. So questions for assessment of learners' understanding cannot be written as direct embodiments of such learning objectives.

So for course writers, the need has remained for:

1. a way to represent the relationships in a topic structure using phrases from ordinary language, so that the inevitable conceptual gaps, ambiguities and contradictions can be revealed easily and removed
2. a way to represent learning objectives as direct uses of the concepts in a topic structure
3. a way to generate assessment questions directly from such conceptually keyed learning objectives – preferably in a natural learning sequence.

A way to meet all three of these needs has been found, starting from Pask's idea of an entailment mesh.

## **Representing relationships in a topic structure using ordinary language**

### *Methodology*

Several years ago at the UK Open University, a way was found for course writers to represent a topic structure using phrases from ordinary language for the relational operators. Such a representation is known within the UKOU as a 'relational glossary' (Zimmer, 1984). It has the same three defining properties which Pask set out for a well-formed entailment mesh: consistency, cyclicity and 'cognitive glue' (Pask, 1975). Within the UKOU, two of these properties have been renamed. 'Cognitive glue' is called connectivity. Cyclicity (which means that if there is a relational path from Concept A to Concept B, then there must be another path from Concept B back to Concept A) has been replaced by closure (which has almost exactly the same effect – it means that any term which appears in a definition in a relational glossary, also must appear as an entry in its own right). As with any of Pask's entailment meshes, the link structure of a relational glossary resembles that of a 'string bag'.

The way in which creation of a relational glossary drives gaps, ambiguities and contradictions out of a topic structure is specific:

- A gap is experienced as a concept, or as an aspect of meaning of a concept, which is missing from a topic structure. It therefore can be eliminated by checks for closure within a relational glossary which represents the topic structure.
- An ambiguity is experienced as an insufficiently specified aspect of meaning of a concept in a topic structure. It therefore can be eliminated by checks for connectivity within a relational glossary which represents the topic structure.
- A contradiction is experienced as aspects of meaning which disagree with one another, across one or more concepts in a topic structure. It therefore can be eliminated by checks for consistency within a relational glossary which represents the topic structure.

The fact that a relational glossary uses ordinary language for its relational operators has three consequences:

- it can be created by ordinary course writers in the normal language of the topic itself
- it can be displayed in a form which looks like an ordinary glossary
- it can be created – if need be – with just pencil and paper.

Computers, however, can have an important role. A relational glossary is much easier to create if a computer is used to keep track of the interconnections within it. Software for doing so has been in use for some time at the UKOU (Heap, unpublished; Woodman et al., 1994).

Not only creation but also display of a relational glossary can be enhanced through the use of a computer. Each entry consists of an explanation of one concept in terms of others. So if the terms which denote the others are made into hypertext links, then clicking on any one of these terms takes the user directly to the entry for the concept which that term represents. The author has helped to create a 1500-term relational glossary covering all of second-year undergraduate physics in this format (Lambourne et al., 1997).

### *Outcomes and evaluation*

Relational glossaries have been created for several UKOU courses. Students have found them very helpful both for revision and for 'getting unstuck'. Authors have found that the act of creating them enforces clarity. Authors working together have found that creating a relational glossary facilitates convergence to shared understanding.

Figure 1 displays an actual example of a relational glossary. It is centered on the concept denoted by the term 'relational glossaries' – so it 'walks its own talk'. It is extensive, so the reader is referred to it for any further desired detail about relational glossaries. (Browsing it is best begun at the term 'relational glossary'. All terms which appear in bold print can themselves be looked up in this glossary.)

Figure 2 displays two important properties of the relational glossary in Figure 1: the connectivity of each concept and the centrality of each concept. (These are defined in detail in the relational glossary itself.) The concepts are arranged in order of decreasing connectivity vertically, and of decreasing centrality horizontally. The result is that 'relational glossary' can be seen to be the most central concept, and the relational-link coverage of the glossary can be seen to concentrate toward centrality.

In the most tightly-knit and well-delineated topic structure possible, the concepts which are most central are also the most connected. That is, those which cite the most other concepts in the topic, also are cited *by* the most other concepts in the topic. If the topic structure in Figure 2 were of this kind, then its shading would darken uniformly toward the upper left-hand corner, with no white spaces (except for the spaces marked X due to self-citation by a concept not counting), and there would be nothing below the black diagonal line.

Unfortunately, no real topic structure is likely to be so well-knit. But the shading in Figure 2 shows that the link coverage of the relational glossary in Figure 1 does approach this ideal.

At the same time, the white spaces show where possible aspects of meaning have been missed. For example, it can be seen in Figure 2 that the term 'connectivity' does not cite the term 'concept'. This suggests that an aspect of meaning for 'connectivity' might usefully be added. If it were, it might say that the connectivity of a concept (or term) is a measure of the degree to which the concept (or term) in the topic (or glossary) is defined in terms of others in the topic (or glossary).

Such room for improvement is the reason for the words 'present end' which appear at the end of the relational glossary in Figure 1. Convergence of this glossary to stability 'for now' has been achieved within a specific context. Any widening of that context would be bound to introduce new gaps, ambiguities and contradictions – thereby setting off a new round of checks for closure, connectivity and consistency.

SUBJECT	PREDICATES
An AMBIGUITY	is experienced as an insufficiently specified <b>aspect of meaning</b> of a <b>concept</b> in a <b>topic structure</b> .
	can be eliminated by checks for <b>connectivity</b> within a <b>relational glossary</b> which represents the <b>topic structure</b> .
	[Compare and contrast with <b>gap</b> and <b>contradiction</b> .]
An ASPECT OF MEANING	of a <b>concept</b> in a <b>topic structure</b> , is a logical relationship which brings one or more additional <b>concepts</b> together in a cluster around the original <b>concept</b> .
	of a <b>term</b> in a <b>relational glossary</b> , is a semantic relationship which brings one or more additional <b>terms</b> or primitives together in a sentence whose subject is the original <b>term</b> .
	of a <b>term</b> in a <b>relational glossary</b> which uses the <b>subject-predicate format</b> , is represented by a predicate phrase following the subject phrase for the <b>term</b> .
	for a <b>term</b> in a <b>relational glossary</b> which uses the <b>subject-predicate format</b> , is kept distinct from other aspects of meaning by the clear separation of the corresponding predicate phrases.
	is exemplified in the <b>subject-predicate format</b> for the <b>term</b> 'ASPECT OF MEANING', by this sentence itself.
	of a <b>term</b> in a <b>relational glossary</b> which uses the <b>term-explanation format</b> , is not represented distinctly at all.
	of a <b>term</b> in a <b>relational glossary</b> which uses the <b>term-explanation format</b> , is muddled together with other aspects of meaning by the variety of grammatical subjects in the explanatory sentences.
CENTRALITY of a <b>term</b> in a <b>relational glossary</b>	is measured by the number of times the <b>term</b> is cited by another <b>term</b> as a cross-reference; citation of a <b>term</b> in a subject phrase is counted for each <b>aspect of meaning</b> in which the subject phrase participates, and every appearance of a <b>term</b> counts.
	can be measured precisely only in the <b>subject-predicate format</b> , which keeps different <b>aspects of meaning</b> distinct.
	cannot be measured precisely in the <b>term-explanation format</b> , which muddles different <b>aspects of meaning</b> together.
CLOSURE in a <b>relational glossary</b>	ensures that all cross-referenced <b>terms</b> appear as entries themselves in the <b>relational glossary</b> .
	eliminates <b>gaps</b> from the <b>topic structure</b> which the <b>relational glossary</b> represents.
	is a syntactic property which can be monitored and verified by a computer.
	enables the <b>topic structure</b> to cohere like a 'string bag', exhibiting what Pask called 'cyclicity'.
	[Compare and contrast with <b>consistency</b> and <b>connectivity</b> .]
A CONCEPT in a <b>topic structure</b>	can be represented by a <b>term</b> in a <b>relational glossary</b> .

Figure 1. A relational glossary centered on the concept denoted by the term 'RELATIONAL GLOSSARIES' [continued over four pages]

CONNECTIVITY in a <b>relational glossary</b>	ensures that all significant logical relationships in the <b>topic structure</b> are represented.
	eliminates <b>ambiguities</b> from the <b>topic structure</b> which the <b>relational glossary</b> represents.
	for each <b>term</b> , is measured numerically by the number of times the <b>term</b> cites another <b>term</b> as a cross-reference; citation of a <b>term</b> in a subject phrase is counted for each <b>aspect of meaning</b> in which the subject phrase participates, and every appearance of a <b>term</b> counts.
	can be measured precisely in the <b>subject-predicate format</b> , which keeps different <b>aspects of meaning</b> distinct.
	generally cannot be measured precisely in the <b>term-explanation format</b> , which muddles different <b>aspects of meaning</b> together.
	is a syntactic property which can be monitored and measured by a computer.
	enables the <b>topic structure</b> to cohere like a multiply connected 'string bag'.
	has been referred to by Pask as 'cognitive glue'.
	[Compare and contrast with <b>consistency</b> and <b>closure</b> .]
CONSISTENCY in a <b>relational glossary</b>	ensures that all <b>aspects of meaning</b> of all <b>terms</b> are logically compatible with one another.
	eliminates logical <b>contradictions</b> from the <b>topic structure</b> which the <b>relational glossary</b> represents.
	is a semantic rather than a syntactic property and so cannot be monitored and measured by a computer (except possibly through sophisticated artificial intelligence).
	enables the <b>topic structure</b> to cohere.
	[Compare and contrast with <b>connectivity</b> and <b>closure</b> .]
A CONTRADICTION	is experienced as <b>aspects of meaning</b> which, for one or more <b>concepts</b> in a <b>topic structure</b> , are not mutually <b>consistent</b> .
	can be eliminated by checks for <b>consistency</b> within a <b>relational glossary</b> which represents the <b>topic structure</b> .
	[Compare and contrast with <b>gap</b> and <b>ambiguity</b> .]
An ENTAILMENT MESH of <b>concepts</b>	is what ordinary course writers might call a <b>topic structure</b> ; it makes the logical links among <b>concepts</b> explicit.
	as formulated by Pask, is the progenitor of a <b>relational glossary</b> – except that its relational operators appear as <b>Polish-notation relational operators</b> <i>outside</i> the <b>concepts</b> being linked.
	has three internal properties which drive <b>gaps</b> , <b>ambiguities</b> and <b>contradictions</b> out of the <b>topic structure</b> to which it corresponds: respectively – cyclicity, 'cognitive glue' and <b>consistency</b> .
	does not show semantic relationships and therefore, relationally, is abstract.
	normally requires a computer for its construction.

Figure 1, continued

A GAP	is experienced as an <b>aspect of meaning</b> , or an entire <b>concept</b> , which is missing from a <b>topic structure</b> .
	can be eliminated by checks for <b>closure</b> within a <b>relational glossary</b> which represents the <b>topic structure</b> .
	[Compare and contrast with <b>ambiguity</b> and <b>contradiction</b> .]
A GLOSSARY	is a collection of explanations of <b>terms</b> which have been arranged in alphabetic order.
	normally does not possess the deliberate <b>consistency</b> , <b>connectivity</b> and <b>closure</b> which are characteristic of a <b>relational glossary</b> .
	can <i>look</i> like a <b>relational glossary</b> without being able to <i>function</i> as a <b>relational glossary</b> .
An IN-FIXED RELATIONAL OPERATOR	is an operator which appears <i>between</i> <b>terms</b> being related. An example from arithmetic is the plus sign in $1 + 1 = 2$ .
	is exemplified in this <b>relational glossary</b> itself by all of the ordinary English connecting words which appear between the subject <b>term</b> and any given cross-referenced <b>term</b> .
	in a <b>relational glossary</b> , shows content-based semantic relationships and therefore, relationally, is concrete rather than abstract.
	[Compare and contrast with <b>Polish-notation relational operator</b> .]
A POLISH-NOTATION RELATIONAL OPERATOR	is an operator which appears <i>outside</i> the <b>terms</b> being related. An example from arithmetic is the SUM operator in $SUM(1,1) = 2$ .
	is exemplified in this <b>relational glossary</b> only by the 'compare and contrast with' operator.
	does not inherently show content-based semantic relationships and therefore, relationally, is abstract rather than concrete.
	[Compare and contrast with <b>in-fixed relational operator</b> .]
A RELATIONAL GLOSSARY	represents a <b>topic structure</b> , using <b>terms</b> to represent <b>concepts</b> .
	looks like an ordinary cross-referenced <b>glossary</b> , but does much more.
	has three specific internal properties which drive <b>gaps</b> , <b>ambiguities</b> and <b>contradictions</b> out of the <b>topic structure</b> which it represents: respectively <b>closure</b> , <b>connectivity</b> and <b>consistency</b> .
	derives from Pask's idea of an <b>entailment mesh</b> ; the difference is that it uses phrases from ordinary language as <b>in-fixed relational operators</b> <i>between terms</i> being linked: these operators are semantically meaningful in terms of sentence content and therefore are relationally concrete.
	can be used by learners to track down misconceptions and get unstuck, whenever they experience <b>gaps</b> , <b>ambiguities</b> or <b>contradictions</b> in a topic presentation.
	can be constructed using, if necessary, just pencil and paper.
	can be used by course authors during its construction, to eliminate <b>gaps</b> , <b>ambiguities</b> and <b>contradictions</b> from their presentations.
	can be used by course authors working <i>together</i> during its construction, in order to converge to a shared <b>topic structure</b> and collection of <b>terms</b> .

Figure 1, continued

The SUBJECT-PREDICATE FORMAT	uses different predicate phrases appended to an invariant subject phrase, to complete different <b>aspects of meaning</b> for each <b>term</b> in a <b>relational glossary</b> .
	keeps different <b>aspects of meaning</b> for a <b>term</b> distinct from one another.
	makes it easier to ensure <b>consistency</b> in a <b>relational glossary</b> , and also makes it possible to evaluate the <b>connectivity</b> and <b>centrality</b> of each <b>term</b> precisely.
	is exemplified by the format of this <b>relational glossary</b> itself.
	generally is considered easier to understand than the <b>term-explanation format</b> .
SYMMETRY in a <b>topic structure</b>	can be displayed visually.
	makes comparisons and contrasts (i.e. analogies) easy to see.
	reveals missing <b>concepts</b> .
	is not displayed by a <b>relational glossary</b> .
A TERM in a <b>relational glossary</b>	is a noun-phrase which represents a <b>concept</b> in the <b>topic structure</b> which the <b>relational glossary</b> represents.
The TERM-EXPLANATION FORMAT	uses paragraphs to explain each <b>term</b> in a <b>relational glossary</b> .
	muddles different <b>aspects of meaning</b> for a <b>term</b> together, since the subjects of the explanatory sentences generally differ.
	makes it hard to ensure <b>consistency</b> in a <b>relational glossary</b> , and also makes it impossible to evaluate the <b>connectivity</b> and <b>centrality</b> of each <b>term</b> precisely.
	generally is considered harder to understand than the <b>subject-predicate format</b> .
A TOPIC STRUCTURE	is a collection of <b>concepts</b> which are meant to be logically interrelated.
	can be represented by a <b>relational glossary</b> .
	also can be given a visual representation which reveals comparison-contrast <b>symmetries</b> (i.e. analogies).
	Present end of this relational glossary about relational glossaries

**Figure 1, concluded**



<div> <div>Concepts in order of decreasing centrality</div> <div>Concepts in order of decreasing connectivity</div> </div>	relational glossary	term	topic structure	concept	aspect of meaning	consistency	ambiguity	connectivity
CONNECTIVITY	9	5	3		3	1	1	
ASPECT OF MEANING	5	9	1	3				
RELATIONAL GLOSSARY		3	3	1		1	3	1
CENTRALITY	3	7			3			
ENTAILMENT MESH	1		2	7		1	1	
CLOSURE	6	1	2			1		1
CONSISTENCY	5	1	2		1			1
SUBJECT-PREDICATE FORMAT	3	3			2	1		1
TERM-EXPLANATION FORMAT	2	3			1	1		1
CONTRADICTION	1		2	1	1	2	1	
AMBIGUITY	1		2	1	1			1
GAP	1		2	1	1		1	
GLOSSARY	3	1				1		1
IN-FIXED RELATIONAL OPERATOR	2	3						
SYMMETRY	1		4	1				
TERM	2		1	1				
CONCEPT	1	1	1					
POLISH-NOTATION RELATIONAL OPERATOR	1	1						
TOPIC STRUCTURE	1			1				
<i>numerical centrality</i>	48	38	25	17	13	9	7	7

**Figure 2. Concept-connectivity vs. concept-centrality matrix for the relational glossary of Fig. 1, showing the number of times the row term cites the column term**

contradiction	gap	subject-predicate format	closure	term-explanation format	centrality	in-fixed relational operator	Polish-notation relational operator	entailment mesh	glossary	symmetry	numerical connectivity
		1	1	1							25
		3		2							23
3	3		1			1		1	1		22
		1		1	X						15
1	1						1	X			15
	1		X								12
1			1								12
		X		1	1						12
		1		X	1						10
X	1										9
1	1										8
1	X		1								8
			1						X		7
						X	1				6
										X	6
											4
											3
						1	X				3
										1	3
7	7	6	5	5	2	2	2	1	1	1	203

Figure 2, concluded. Darker shading denotes higher numerical values. X denotes the exclusion of terms citing themselves, from the definitions of connectivity and centrality

## Representing learning objectives as direct uses of the concepts in a topic structure

### *Methodology*

A way has been found to link the individual concepts in a topic structure – as represented by the individual terms in a relational glossary – to universally relevant learning objectives. The key is a 2x2x2 learning-objectives matrix. This matrix is shown in Figure 3. The phrases in brackets beneath it show how its three axes are to be read, and in what order.

### *Outcomes and Evaluation*

The three axes of the matrix define eight cells which form a logically complete set and which do not overlap. Each cell in the matrix is named individually as an action to be performed on a particular concept. The eight actions fall into a natural learning sequence, and this sequence forms a highly symmetric pattern through the matrix. [A more detailed explication of this matrix is underway (Zimmer, in preparation).]

## Generating assessment questions from the learning objectives in a naturally formative learning sequence

### *Methodology*

The first cell in the matrix in Figure 3 concerns initial acquisition of the concept, so it need not be included for normal assessment purposes. Equally, the last two cells are more suitable for assessment of independent project work, so they too need not be included. This leaves five cells, Cells 2 through 6, as relevant for normal assessment purposes. It may be reassuring that some of these cells have a familiar ring to them. Cells 2, 3 and 4 are about – respectively – what the learner knows, understands and can do (Bloom, 1956). And Cells 5 and 6 get into the area to which Brian Lewis referred as 'explaining and justifying' (Lewis, 1973).

These cells define specific learning objectives for each term in a relational glossary.

### *Outcomes and evaluation*

Figure 4 displays assessment questions which have been generated by applying the five learning objectives in Cells 2 through 6 to the concept represented by the most central term in the relational glossary in Figure 1 – i.e. a term identified in Figure 2 as 'relational glossary'. These questions, together with their answers, can be seen to follow a naturally formative concept-use sequence for learning about the concept of relational glossaries. (The unused Cells 1, 7 and 8 are included in grayed-out form in Figure 4 for completeness.)

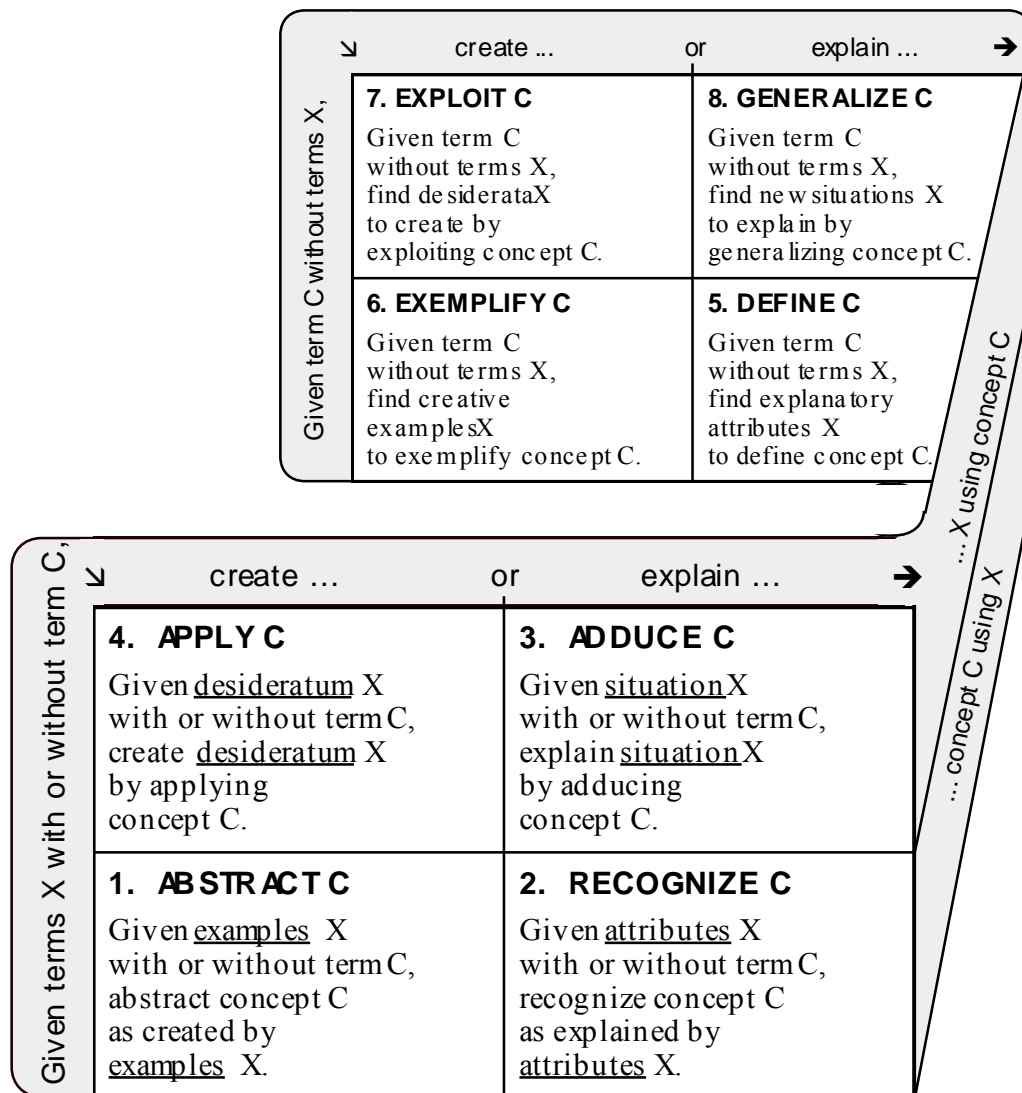
Figure 5 shows how these very same assessment questions cover the learning objectives for all of the other concepts in the topic (as represented by terms in the relational glossary), these being arranged in order of decreasing centrality. (Coverage by questions and coverage by answers to questions are not differentiated.)

Not surprisingly, there is occasional lack of coverage. For example, Figure 5 shows that for some quite central concepts C in the topic (as represented by terms in the glossary), the learning objective 'Apply Concept C' is not asked for by any assessment question at all. In particular, white spaces in the figure suggest that the terms 'topic structure' and 'concept' could use more attention.

Equally, there can be a lot of overlapping coverage – especially since every mention of a term in a question asks for recognition (Objective 2) of that term and of the concept which it represents. So, for example, it can be seen that every question except Q7 asks for recognition of the term 'relational glossary'.

Nevertheless, coverage for the most central terms is good, as shown by the relative absence of empty spaces above the black diagonal line. And coverage for the less central terms is maintained for the simpler learning objectives. This means that if assessment questions are written by means of this technique to cover the most central concepts in a topic, then the very same questions are likely to cover the learning objectives for the other concepts adequately as well – thus saving a lot of time in question-writing.

At least one alternative strategy exists: it is to treat each learning objective for each concept as a separate node, and then to make a learning-objective entailment mesh out of the whole lot. Each node in this kind of structure becomes, for example, 'Adduce Concept C', or 'Apply Concept C', etc., instead of simply 'Concept C'. This exhaustive procedure has been used in some UKOU courses over the years to create teaching sequences and to check assessment-question coverage. But for routine generation of relevant assessment questions, the procedure outlined in the paragraph above is much more efficient.



{ Given terms X with or without term C, { create } { X using concept C. }  
 { Given term C without terms X, explain } { concept C using X. }

Figure 3. The 2x2x2 learning-objectives matrix for generating assessment questions around concepts in a topic structure (or around terms in a relational glossary)

### 1. Abstracting the concept 'RELATIONAL GLOSSARY'

### 2. Recognizing the concept 'RELATIONAL GLOSSARY'

- Q1. What is the average **connectivity** of the **terms** in the **relational glossary** shown above?  
*Average **connectivity** = 203 cross-references / 19 **terms** = 10.7 cross-references per **term***
- Q2. Which **term** in the **relational glossary** shown above has the highest **connectivity**?  
*'CONNECTIVITY': **connectivity** for the **term** 'CONNECTIVITY' = 25 cross-references.*

### 3. Adducing the concept 'RELATIONAL GLOSSARY'

- Q3. Which **term** in the **relational glossary** shown above has the highest **centrality**?  
*'RELATIONAL GLOSSARY': **centrality** = 48 cross-references.*
- Q4. What is the difference between a **term** in a **relational glossary** and a **concept** in a **topic structure**?  
*A **term** in a **relational glossary** represents a **concept** in a **topic structure**.*
- Q5. What is an **aspect of meaning** for a **term** in a **relational glossary**?  
*An **aspect of meaning** is a logical relationship which brings together one or more **concepts** in a cluster around the **concept** which the given **term** represents. It is displayed explicitly in the **subject-predicate format** for a **relational glossary**, as the **term's** subject phrase followed by a particular predicate phrase.*
- Q6. Which format for a **relational glossary** keeps different **aspects of meaning** distinct?  
*Only the **subject-predicate format** for a **relational glossary** does so. The **term-explanation format** muddles different **aspects of meaning** together.*
- Q7. What is the difference between a **gap**, an **ambiguity** and a **contradiction**?  
*A **gap** is experienced as a missing **aspect of meaning** – or an entire missing **concept** – in a **topic structure**. An **ambiguity** is experienced as an insufficiently specified **aspect of meaning**. A **contradiction** is experienced as **aspects of meaning** which are not mutually **consistent**. All three faults can be removed to any desired degree by increasing, respectively, the **closure**, **connectivity** and **consistency** of a **relational glossary** representing the **topic structure**.*

### 4. Applying the concept 'RELATIONAL GLOSSARY'

- Q8. Show how the **relational glossary** above gets rid of **gaps** in the **topic structure** which it represents.  
*This can be done by demonstrating that the **relational glossary** above has **closure**. Or conversely, if you find what for you is indeed a **gap** – a missing **aspect of meaning** or a missing whole **concept** – then try to fill it in.*
- Q9. Show how the **relational glossary** above gets rid of **ambiguities** in the **topic structure** which it represents.  
*This can be done by demonstrating that the **relational glossary** above has high **connectivity**. Or conversely, if you find what for you is indeed an **ambiguity** – an insufficiently connected **aspect of meaning** – then try to amend it.*
- Q10. Show how the **relational glossary** above gets rid of **contradictions** in the **topic structure** which it represents.  
*This can be done by demonstrating that the **relational glossary** above has **consistency**. Or conversely, if you find what for you is indeed a **contradiction** – a lack of **consistency** between two or more **aspects of meaning** – then try to resolve it.*

Figure 4. Assessment questions generated with the learning-objectives matrix in Fig. 3 for the central concept 'RELATIONAL GLOSSARY' in the relational glossary in Fig. 1

## 5. Defining the concept 'RELATIONAL GLOSSARY'

- Q11. What three defining attributes does a **relational glossary** have?  
*Consistency, connectivity and closure.*
- Q12. Does a **relational glossary** display its three defining attributes in a visually obvious way?  
*No. A **glossary** easily can be constructed which looks like a **relational glossary** but which is not one and which does not function as one. The attributes have to be built in.*
- Q13. What is it that a **relational glossary's** three defining attributes enable it to do?  
*They enable a **relational glossary** to eliminate **gaps, ambiguities** and **contradictions** from the **topic structure** which it represents.*
- Q14. Because it can do this, what does a **relational glossary** enable learners to do?  
*A **relational glossary** enables learners to track down their misconceptions and get unstuck, when they experience apparent **gaps, ambiguities** or **contradictions**.*
- Q15. Equally, what does a **relational glossary** enable course authors to do?  
*A **relational glossary** enables course authors to eliminate **gaps, ambiguities** and **contradictions** from their presentations, and – if working together – to converge rapidly to a shared **topic structure** and vocabulary (i.e. collection of **terms**).*
- Q16. How does a **relational glossary** differ from a **topic structure**?  
*A **relational glossary** consisting of **terms**, represents a **topic structure** consisting of **concepts**.*
- Q17. How does a **relational glossary** relate to an **entailment mesh**?  
*A **relational glossary** represents a **topic structure** – i.e. an **entailment mesh** of **concepts** – but differs by using phrases from ordinary language as **in-fixed relational operators**.*
- Q18. Can a **relational glossary** use **Polish-notation relational operators**?  
*Yes, but only for the 'compare and contrast' operator. **Polish-notation relational operators** need not draw on the meanings of **terms** being related and therefore can operate relationally in the abstract. A **relational glossary** does draw on the meanings of **terms**.*
- Q19. How does a **relational glossary** resemble a 'string bag'?  
*If the **relational glossary** is well-**connected, consistent** and **closed**, then any of its **terms** can be used as the 'head' **term** from which all of the others relationally 'hang'. This is true for **entailment meshes** in general.*
- Q20. Which important possible property of a **topic structure** does a **relational glossary** not display either in **subject-predicate format** or in **term-explanation format**?  
*A **relational glossary** does not display comparison-contrast **symmetry** due to analogy, i.e. **Concept X** is to **Concept Y** as **Concept A** is to **Concept B**. Such **symmetry** can be seen only if the **conceptual** clusters in the **relational glossary** are made visually apparent and then are carefully arranged with respect to one another.*

## 6. Exemplifying the concept 'RELATIONAL GLOSSARY'

- Q21. Choose a topic of your own liking and construct a **relational glossary** for its **topic structure**.  
*One can use the **subject-predicate format** with **in-fixed relational operators**: it is much clearer than the **term-explanation format**. One can be alert for relationships as yet unformulated, and use these to create as many **aspects of meaning** for each **term** as one can, thereby building the **relational glossary**. One can note any **gaps, ambiguities** and **contradictions** which are encountered, and build in enough **closure, connectivity** and **consistency** to eliminate them.*

## 7. Exploiting the concept 'RELATIONAL GLOSSARY'

## 8. Generalizing the concept 'RELATIONAL GLOSSARY'

Figure 4, concluded. Terms in bold print are terms in the relational glossary in Fig. 1

Concept C	Objective 2	Objective 3	Objective 4	Objective 5	Objective 6
	Recognize C	Adduce C	Apply C	Define C	Exemplify C
RELATIONAL GLOSSARY	1→2 3→6, 8→21	3→7	8→10	11→20	21
TERM	1, 2, 3, 4, 5	1, 2, 5, 15, 16, 18, 19	1, 21	4	21
TOPIC STRUCTURE	4, 8, 9, 10, 16, 20, 21	4, 7, 13, 15, 16, 17		17	
CONCEPT	4	4, 5, 7, 8, 16, 17, 20			
ASPECT OF MEANING	5, 6	6, 7, 8, 9, 10	21	5	21
CONSISTENCY		7, 11, 19	10, 21		
AMBIGUITY	7, 9	9, 13, 14, 15, 21		7	
CONNECTIVITY	1, 2	1, 2, 7, 11, 19	2, 9, 21		
CONTRADICTION	7, 10	10, 13, 14, 15, 21		7	
GAP	7, 8	8, 13, 14, 15, 21		7	
SUBJECT-PREDICATE FORMAT	20	5, 6	21		
CLOSURE		7, 11, 19	8, 21		
TERM-EXPLANATION FORMAT	20	6, 21			
CENTRALITY	3	3			
IN-FIXED RELATIONAL OPERATOR		17, 21			
POLISH-NOTATION RELATIONAL OPERATOR	18	18			
ENTAILMENT MESH	17	17, 19			
GLOSSARY		12			
SYMMETRY		20			

**Figure 5. The concept-centrality vs. concept-use matrix for checking coverage by the assessment questions in Fig. 4. (Numbers are question numbers)**

## *Summary and opportunities*

This paper has shown how a given topic can be transformed into

- a conceptual topic structure represented by a relational glossary which is consistent, well-connected and fully closed, together with
- a sequence of learning objectives which, for each concept in the topic structure, is formative and complete – plus
- a set of assessment questions which supports each formative learning objective to any desired degree
  - (a) for the central concept, completely – and
  - (b) for the other concepts, proportionally to their centrality.

This outcome represents a significant integration of cogent teaching with assessment which is relevant and fair.

The tools which have made this integration possible are, respectively,

- a consistent, well-connected and closed relational glossary representing the topic structure, which is intersected with
- a 2x2x2 learning-objectives matrix, which has within it
- a naturally formative learning sequence for any given concept in the topic structure.

Development of the first of these tools, the relational glossary, was inspired by Pask's definition of an entailment mesh; the relational glossary in its three central criteria attributes remains faithful to his original vision. The main differences between a topic structure represented by a relational glossary and an entailment mesh are that, in a relational glossary,

- the terms representing concepts are arranged alphabetically rather than spatially,
- the relational operators are infix among the terms rather than external, and
- the relational operators are phrases from ordinary language rather than formal operators.

This means that a relational glossary can be created by ordinary course writers using just the language of their chosen topic. No recourse to a meta-language for specifying conceptual relationships is necessary.

Development of the second tool, the 2x2x2 learning-objectives matrix, proceeded directly from the need to be able to specify learning objectives in terms of the concepts in a topic structure. It is designed for use with the terms in a relational glossary which represents the topic structure.

Development of the third tool, the formative learning sequence within the 2x2x2 matrix, arose naturally in turn.

For all three of these tools, Pask was the inspiration.

Each of these three tools is shown in actual use in this paper, and each use is worked through in complete detail. The reader who wishes to learn to use these tools is invited to use this paper as a resource.

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